PO-0855

Modelling the dosimetric effects of seminal vesicles and lymph nodes irradiation during prostate-based couch shift

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Purpose/Objective: The aim of this study was to examine the influence of interfraction prostate (CTV1) positioning on the doses delivered to seminal vesicles (CTV2) and lymph nodes (CTV3) and to determine set-up margin size for those targets while performing on-line prostate-based position verification.
Materials and Methods: Prospective analysis based on 253 CBCT studies of 28 patients with CTV1-3 simultaneous IMRT irradiation was evaluated to determine prostate motion in relation to the coordinate system of bony anatomy. The isocenter-shift method was used to estimate the interfraction prostate-of-the-day and bony shifts' influence on original (ORG) plans' coverage, finally giving 2 additional groups of plans (prostate-based PB and bony-based BB) to compare.
Results:

	Minimum			Maximum			Mean		
	ORG	BB	PB	ORG	BB	PB	ORG	BB	PB
SEMINAL VESICLES									
MEAN [%]	98.73	98.58	98.07	103.03	102.46	102.38	100.70	100.53	100.57
SD [%]	1.05	1.36	1.79	1.16	0.93	0.86	0.78	0.79	0.83
MED [%]	98.60	98.75	98.33	102.90	102.27	102.27	100.50	100.50	100.50
LYMPH NODES									
MEAN [%]	95.08	93.16	92.45	105.81	104.60	104.63	101.10	100.97	100.94
SD [%]	3.82	5.00	5.16	1.17	1.09	1.04	0.71	0.98	0.81
MED [%]	95.95	94.44	93.92	105.80	105.00	104.55	100.95	100.96	100.91

The tracked shifts influenced CTV2-3 doses within the difference of 0.17%-2.63% (prostate shifts) and 0.13%-1.92% (bony shifts) from corresponding original parameters. Detailed descriptive statistics are presented in the Table. Based on Friedman's test, the statistically significant reduction for CTV3 minimum and both CTV3 and CTV2 maximum doses were found. According to post-hoc analysis (two-tailed Nemenyi's test), the responsibility for founding differences was mainly detected between original and prostate-based plans. Out of 253 verifications, 99% of the analyzed target's volume was not enclosed by 95%-isodose (which was considered as inconsistent coverage) during 34 (13.44%) and 14 (5.53%) prostate-based isocenter shifts, which affected CTV3 and CTV2 minimum doses, respectively. In contrast to bony-based set-up, in this case prostate was irradiated correctly. The values detected for bony-based isocenter shifts demonstrated inconsistent coverages during 33 (13.04%) simulated fraction distributions for CTV3, among which inconsistent coverages for CTV2 were also determined 9 times. In this part of the analysis, the correlation between dose delivery degradation and the accuracy of the original coverage was found. Thus, on the basis of prostate motion analysis, set-up margins calculated according to van Herk formula equalled 12.18 mm, 1.93 mm and 3.87 mm in vertical, longitudinal and lateral direction, respectively.
Conclusions: To avoid the geographical miss during simultaneous irradiation of independently moving targets (CTV1-3), appropriate margins should be applied, which take into account the position verification strategy used. Different variables existing in clinical practice (like intrafraction prostate motion, possible variations of seminal vesicles localization, lymph nodes position stability with respect to pelvic vasculature and bones, frequency of on-line prostate-based verification and magnitude of shifts applied in each anatomical direction observed in the study group), forced us to modify 'population-based' margins into 7 mm for prostate, 8-9 mm for seminal vesicles and asymmetric 10 mm in vertical direction with 5 mm in other axes for lymph nodes.

PO-0856

CTV-to-PTV margin determination in the presence of IGRT by means of deformation analysis using image registration

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Purpose/Objective: One benefit of IGRT is the potential for PTV margin minimization. This margin reduction optimization is mainly limited by deformations causing random positioning errors in fractionated therapy. There is a need for a clinical concept or recipe that allows determining the residual necessary CTV-to-PTV margin in the presence of daily IGRT. As a first order approximation for this margin determination a probability based approach is used.
Materials and Methods: 11 head and neck cancer (HNC) patients with daily kV CT scans (318 scans) were used for this retrospective analysis. All patients were positioned using a stereotactic frame with attached scotch-cast mask and vacuum mold fixation. In all patient datasets, the volumes of interest ($VOIs_{pln}$) CTV1, CTV2 and the spinal cord (SC) were considered in this analysis. A deformable image registration method was used to determine the varying anatomical deformations as well as to re-contour all VOIs on each fraction CT ($VOIs_{dir}$). Additionally, an IGRT correction calculated using rigid registration limited to the CTV2 region was simulated for each treatment fraction. All $VOIs_{dir}$ were transformed corresponding to the calculated inverse rigid correction (including rotations) to $VOIs_{dir+T,}$ representing the VOI position and shape after the systematic setup correction. These VOIs were used to calculate the volume fractions lying outside the initially planned $VOIs_{pln}$ plus a varying isotropic margin (CTV1: from 0 to 5 mm in 1mm steps; CTV2 from 0 to 10 mm in 1 mm steps; SC 5mm (fixed)). The probability matrices to miss >2%/>5% of each target volume for the varying margin sizes were calculated considering all fractions of all patients equally.
Results: If 5%/2% of each target volume to be missed istolerated and no interim re-planning is considered, a necessary CTV-to-PTV margin extension of (2.9&3.5) mm/(4.1&6.5) mm is required (for CTV1& CTV2) to cover at least 90% of all fractions in our patient cohort. To increase the probability of target coverage to at least 95% the same margins increase to (4.5&9.5) mm/(>5&>10) mm. A detailed analysis revealed that, most fractions with high miss-probability belonged to 3 out of 11 patients only and were not distributed uniformly along all patients.
Conclusions: The presented method can help to approximate the minimal CTV-to-PTV margin in the presence of daily IGRT for a selected patient cohort. In our exemplary HNC patient cohort a 3&3.5 mm minimal margin for CTV1 and CTV2 is indicated with an acceptance of a 90% probability to cover at least 95% of each target volume. Yet, the results encourage further development for a selective identification of candidates for re-planning.

POSTER: PHYSICS TRACK: IMAGING: FOCUS ON CLINICAL APPLICATIONS

PO-0857

Speed of sound aberration correction for volumetric prostate imaging in ultrasound based image guided radiotherapy

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Purpose/Objective: Ultrasound-guided radiotherapy (US-gRT) may suffer from density induced speed of sound (SOS) artifacts when SOS differs from the standard value used in US imaging (1540 m/s, an average value for human soft tissues). The purpose of this work was to evaluate the magnitude of this aberration on three-dimensional (3D) imaging of prostate. To this end, a volumetric correction algorithm was introduced, based on density information provided by a co-registered CT scan. Reliability and robustness of the method were demonstrated.
Materials and Methods: An extension of a method, for density-based SOS aberration correction, to 3D US image volumes produced by any generic US probe was introduced. The algorithm is applicable to a general case where the lines of view (LOV) of the US device are not necessarily parallel and coplanar, thus allowing correction also for US transducers other than linear. The algorithm automatically defines the LOVs of the probe from the US image and applies the cumulative correction along them. To prove its reliability, the algorithm was applied on a multi-modality pelvic US phantom, scanned through three different liquid layers on top of the phantom with different SOS values. The liquids were chosen with a large range in SOS values to ensure a proper coverage of all possible human soft tissue values: from 1460 m/s for sunflower oil; to 1665 m/s for 17% saline solution; mimicking respectively the extreme values of fat and muscle. After the correction the positions of the internal phantom structures were compared to their known positions (from the CT scans). The robustness of the algorithm was also extensively tested against variation of the empirical parameters involved. Then fifteen clinical

cases of prostate cancer patients from three different hospitals were investigated: a comparison of the US images before and after the correction was performed (Fig. 1) and the shifts of the center of the prostates reported.

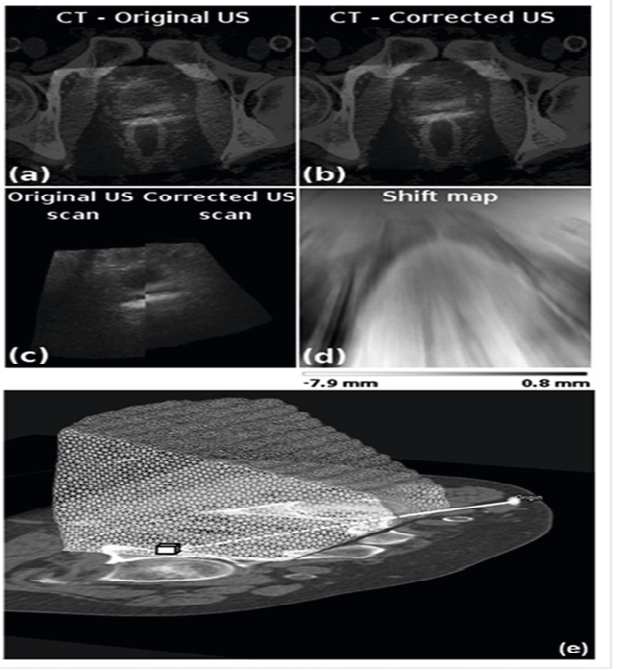

Fig. 1: An example of a prostate clinical case: Superposition in an axial projection of the CT scan with the US scan before (a) and after (b) application of the SOS aberration correction. (c) Comparison of the split US scans before and after the correction. (d) Map of the distribution of voxel shifts after application of the SOS aberration correction. (e) 3D visualization of US volume superimposed on the axial CT slice of the patient; in white, the LOV connecting the origin to the voxel where the correction has to be applied.

Results: On the phantom, the correction restored a better match between the CT and the US images, reducing the differences to sub-millimeter agreement for all three liquids. The SOS aberration corrections of prostate centroids were on average +3.1 mm (max +4.9 mm – min +1.3 mm) (Table1). This is in excellent agreement with reports in the literature on differences between measured prostate positions by US and other techniques, where often the discrepancy was attributed to other causes.

Patient	Prostate shift (mm)
1	2.7
2	3.9
3	1.3
4	3.4
5	2.9
6	3.6
7	2.1
8	2.5
9	4.3
10	3.2
11	4.9
12	2.4
13	4.1
14	2.4
15	2.8
Average	3.1
Standard deviation	0.9

Table 1: Shifts of the prostate center obtained as average of the proximal and distal wall positions at prostate maximum diameter along the LOV of the US system, for fifteen clinical cases. The correction shifts the prostate upwards, which means the real position is shallower than shown on uncorrected US images.

Conclusions: The US imaging of the pelvic multi-modality phantom proved that the algorithm restores a match between the CT and the US scans very similar to what would be obtained through a manual registration. The test on clinical cases of 15 prostate cancer patients showed an average shift of the prostate center position confirming that the reported discrepancies between US and other IGRT methods, both in direction and magnitude, can be largely explained by SOS aberration. Our recommendation is therefore that US-IGRT should include SOS corrections for accurate imaging.

PO-0858

Geometric accuracy of spinal cord MRI for high dose, single fraction, VMAT treatment of spinal oligometastasis

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Purpose/Objective: Stereotactic radiosurgery (SRS) is increasingly employed for spinal oligometastasis. For vertebral lesions near the spinal cord, high accuracy is imperative. Routine use of MRI in SRS permits visualization and contouring of the spinal cord instead of the spinal canal. The cerebrospinal fluid (CSF) then no longer serves as an implicit organ-at-risk margin. However, spinal cord movement within the CSF is conceivable. In this study, we aim to determine the extent of (perceived) spinal cord motion as a consequence of MR artefacts and subject positioning.

Materials and Methods: MRI series of 8 volunteers were collected at different spine locations (C7, T8 or L2), consisting of combinations of T1, T2 weighted and cine MRI sequences. Data was acquired on a 1.5T scanner; resolutions 0.5x0.5x2 mm^3 (T1, T2) and 0.6x0.6x10 mm^3 (cine). In some scans, the water-fat shift (WFS) direction and -magnitude was deliberately altered to determine the impact on (perceived) spinal cord location. To assess the influence of subject positioning, spine orientation was changed with cushions and subjects were repositioned twice. Respiration effects were evaluated on free breathing cine MRI. Analysis involved rigid vertebral body registration,